



# NATIONAL WEATHER SERVICE

## Building a Weather-Ready Nation



## Forecast and evaluation of high aerosol events using Global Forecast model at NOAA/National Weather Service

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# Towards replacing GFS based NGACv2 with GEFS based system

*Current work is collaboration between NOAA-ESRL/GSD & NWS/EMC*

- **FV3GFS** was coupled to a NUOPC chemistry component (the WRF-Chem chem\_driver) and using simple bulk aerosol modules from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) aerosol module. The dust module was replaced with FENGSHA and a 1-d wind shear dependent cloud model was used to determine injection heights from biomass burning region.
- Impacts of different fire emissions (MODIS, GBBEPx) and plume rise application were extensively evaluated against observation before finalizing the final configuration.
- It will be placed as a member in the Global Ensemble Forecast System (GEFS) version 12 and named as **GEFS-Aerosols**.
- **GEFS-Aerosols** slated to replace current operational NEMS GFS Aerosol Component (NGACv2) in late summer 2020.



## Salient features of GEFS-Aerosols in GEFS v12

- **Resolution:** c384 (~25km horizontal resolution) L64 to 5 days, 6-hourly global forecast and 4x/day (00, 06, 12 and 18)
- **Meteorology :** GEFS, based on GFSv15
- **Aerosol :** Inline aerosol representation based on GOCART (Dust, Organic and Black carbon, Sea-salt, Sulfate)
- **Transport:**
  - Sub-grid scale tracer convective transport and wet scavenging included in GFS-Physics - SAS scheme and planetary boundary layer (PBL)
  - Fluxes are calculated positive definite
- **Deposition:**
  - Wet deposition (for aerosols and sulfate) and dry deposition (all species)
- **Anthropogenic Emissions:** CEDS-2014 (SO<sub>2</sub>, PSO<sub>4</sub>, POC, PEC)
- **Biomass burning:** NESDIS Global Biomass Burning Emission Product (GBBEPx) used for fire size and location (Zhang et al., 2012); 1d wind shear-dependent cloud model used to simulate plume tilt and Fire Radiative Power (FRP) is used to determine injection heights and emission rates online
- **Dust:** 5 size bins
  - FENGSHA dust scheme: scheme used in current NAQFC (Tong et al. 2016)
- **Sea-salt:** NASA GEOS-5 GOCART
- **Marine Dimethyl Sulfide:** GOCART with monthly values as in Lana et al. (2011)



# GEFS-Aerosols Products

**GEFS-Aerosols provides 0.25, 0.5 and 1x1 degree forecast products in GRIB2 format 4 times per day**

Product files and their contents include:

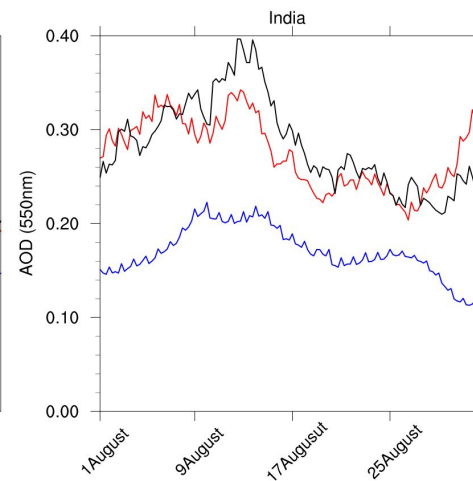
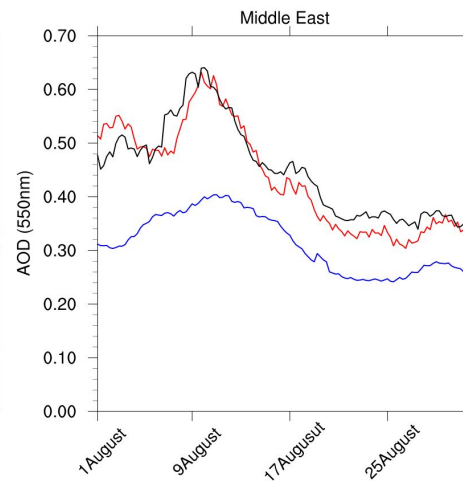
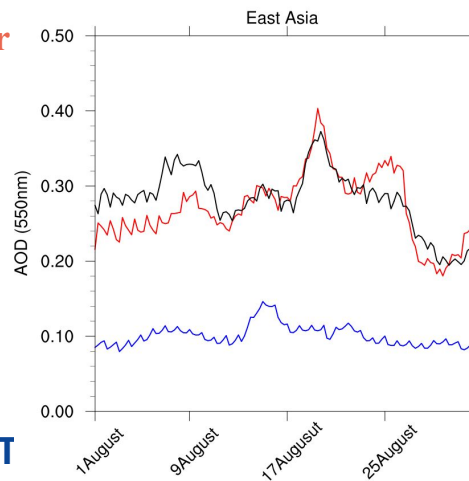
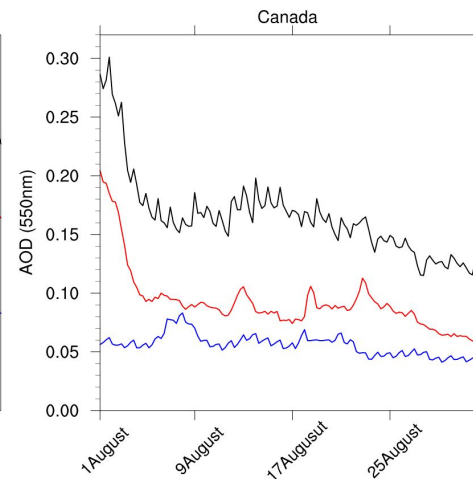
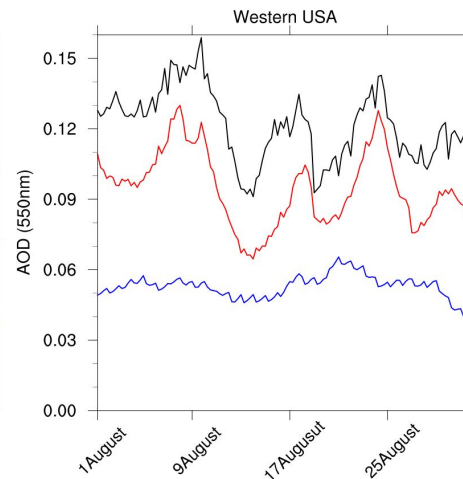
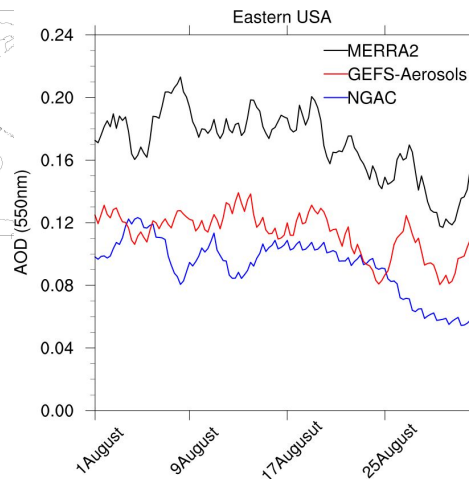
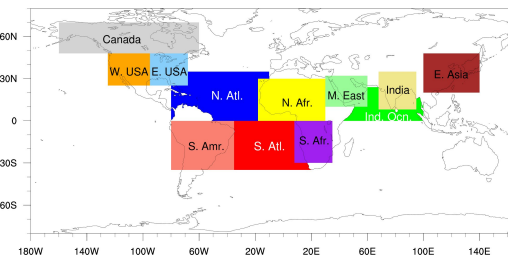
- ❑ 2d fields : Aerosol Optical Depth (AOD) at 340, 440, 550, 660, 860, 1063 and 1110nm from 0-120 hours
- ❑ PM10 and PM2.5 for 0-120 hours.
- ❑ Total AOD at 550nm contains fields from all 5 species (dust, sea-salt, carbonaceous aerosols, sulfate AOD) along with emission, sedimentation, dry deposition and wet deposition fluxes.
- ❑ Single scatter albedo and asymmetric factor for total aerosols at 340nm
- ❑ 3d fields : Aerosol mixing ratios of species at model levels along with pressure, temperature and RH.

◆ **results from daily model forecasts between July – December, 2019**  
◆ **AOD at 550nm used for verification with observation**

# Verification Dataset

- ☐ 6-hourly AOD forecast from International Cooperative for Aerosol Prediction Multi-model Ensemble (ICAP-MME) (Peng et al., 2019) – ICAP *uses data assimilation*
- ☐ AOD analysis from MERRA2 (Randles et al., 2017)
- ☐ Daily MODIS total AOD from collection 6.1 - combined dark target and deep blue (DT and DB)
- ☐ Daily VIIRS AOD at 0.25x0.25 degree
- ☐ Total AOD from AERONET station data – Version 3, level 1.5

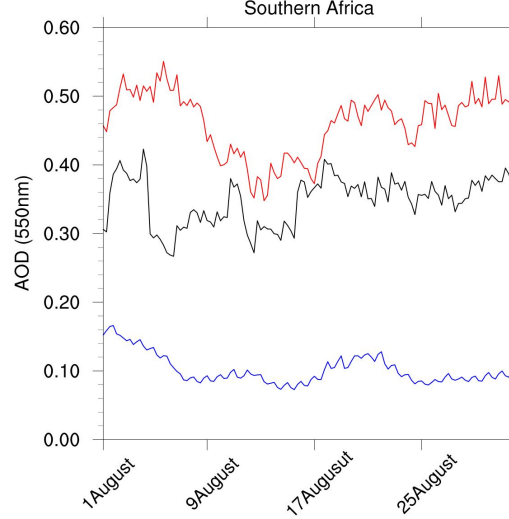
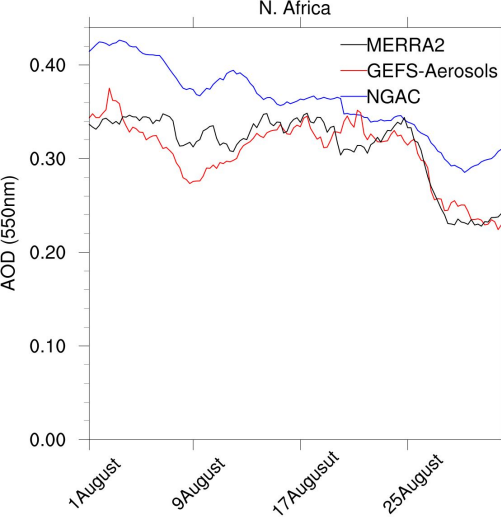
## Day 1 total AOD forecast time series against reanalysis : August, 2019



**GEFS-Aerosols show major improvement over anthropogenic pollution regions**

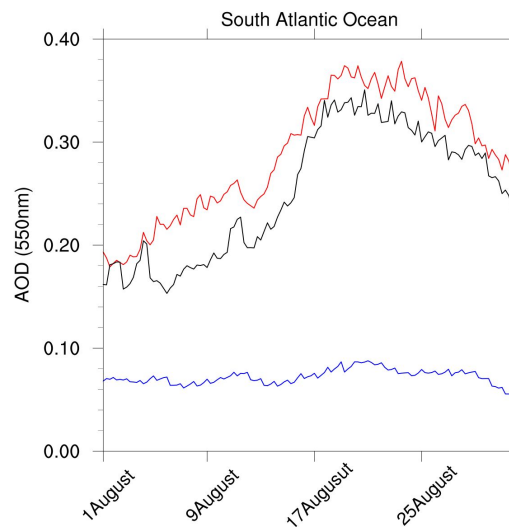
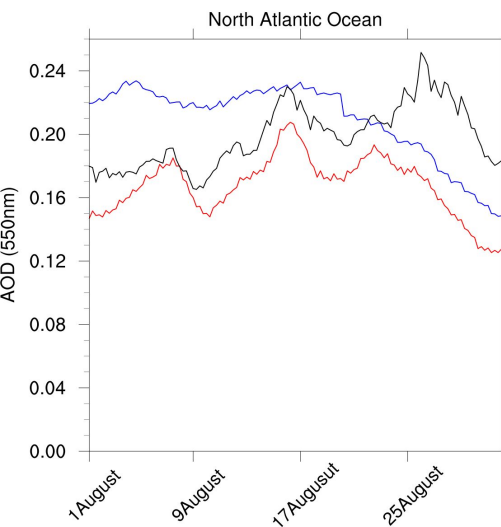


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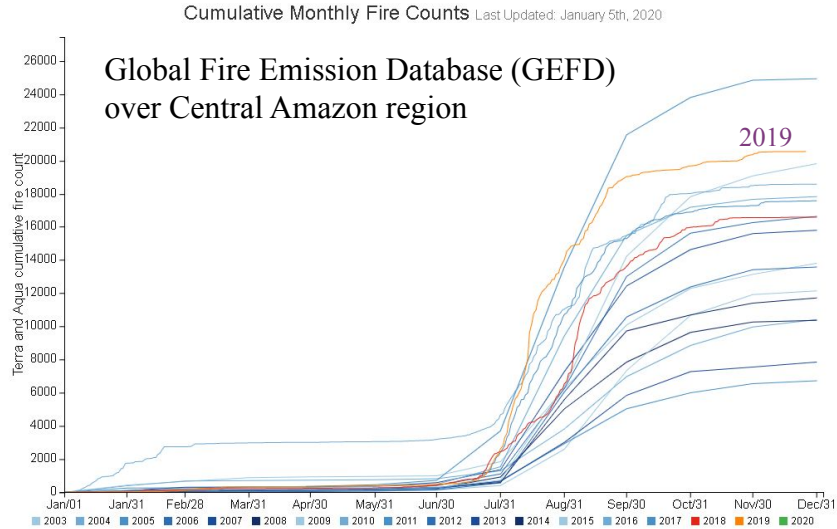
Day 1 total AOD forecast time series against reanalysis :  
August, 2019

- **Saharan dust dominates AOD over N. Africa and NGACv2 over predicts dust around the source region**
- **Transport of OC/BC/Sulfate from African wildfire (S. Atlantic Ocean) is well captured by GEFS-Aerosols. However, it over predicts over wildfire source region in land (Southern Africa)**

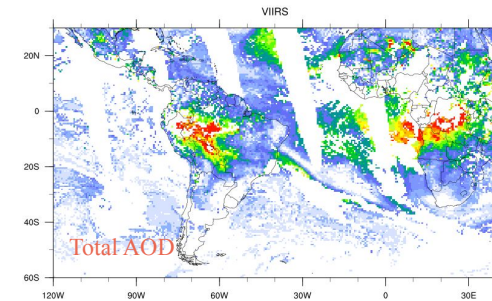
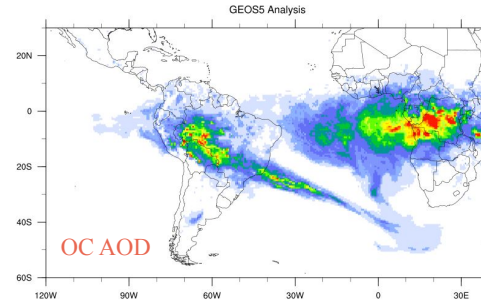
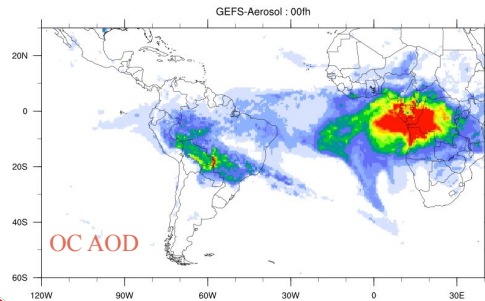


## High aerosol event : Wildfire in Amazon, 2019

- Extensive number of fires raged throughout Brazil in 2019, intensifying in August – drought stressed forest fueled Amazon fire

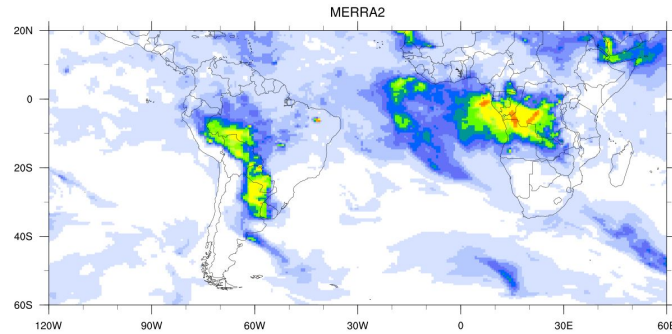
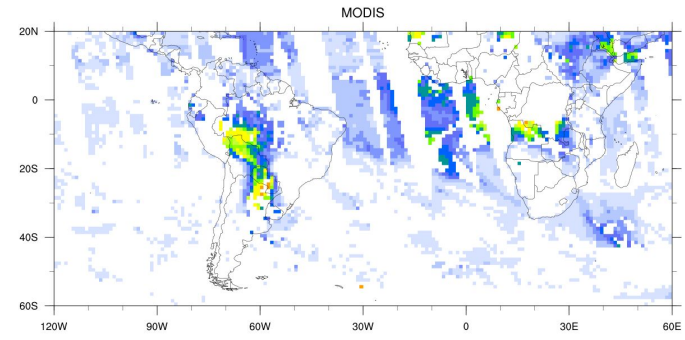
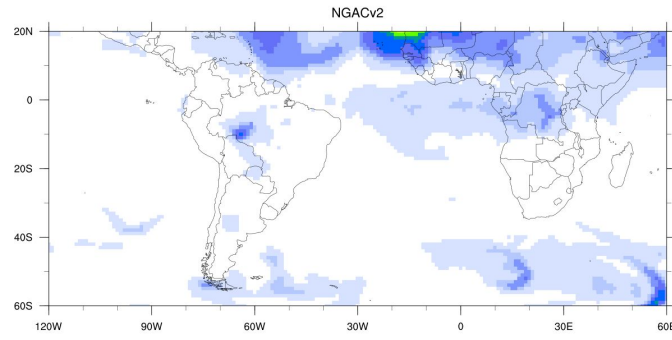
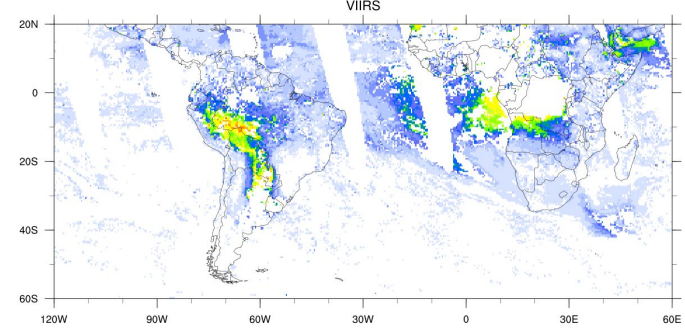
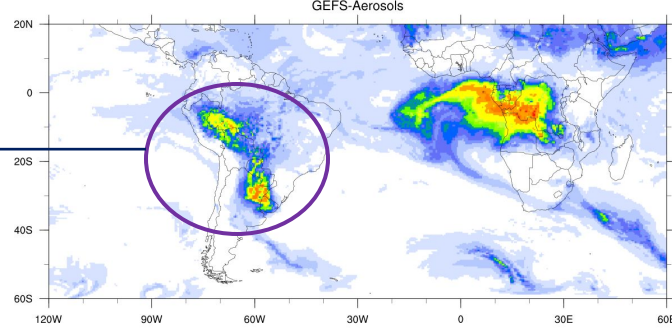


Organic Carbon (OC) AOD : 21<sup>st</sup> August





Amazon fire

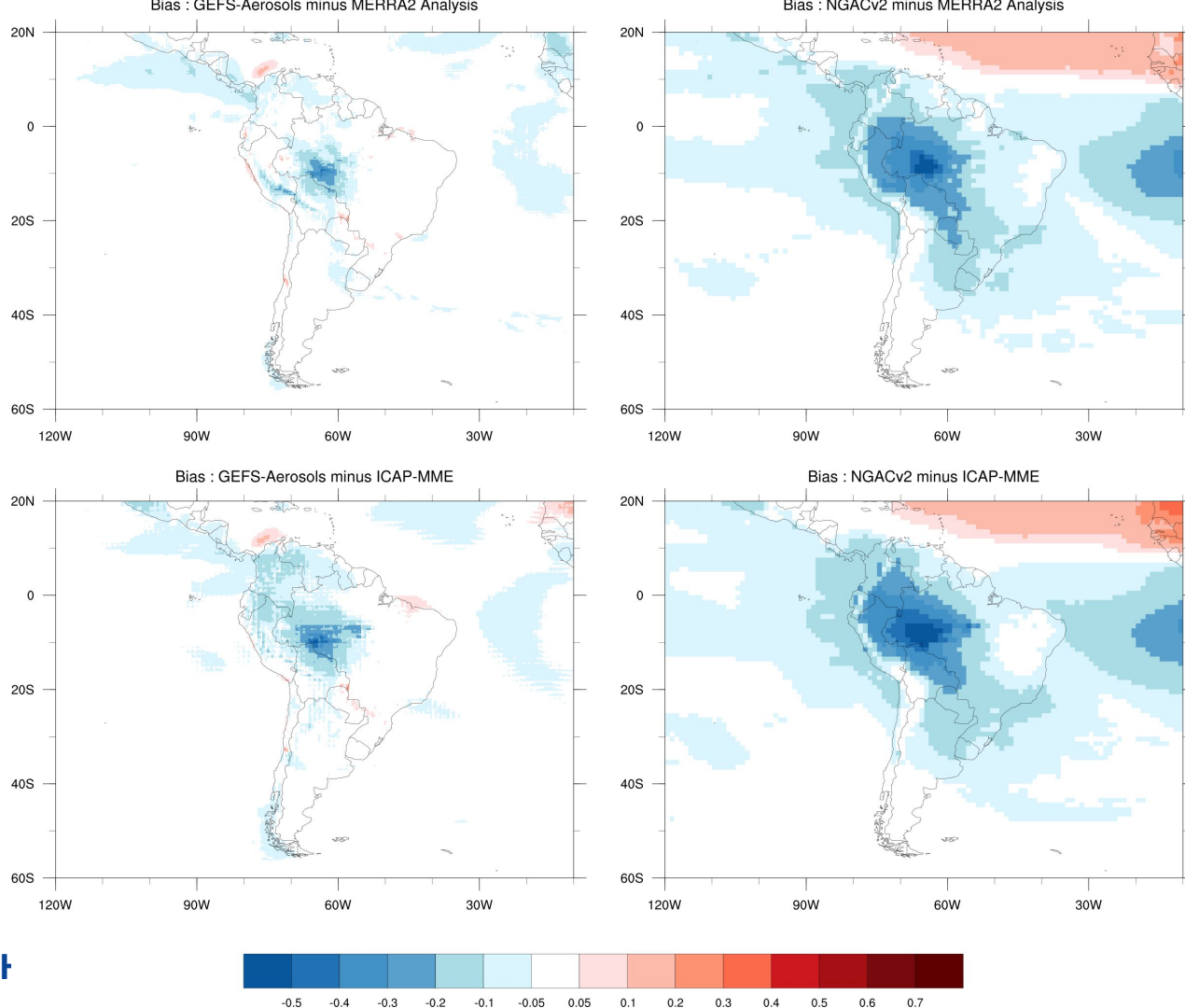


24-hour total AOD forecast on 25<sup>th</sup> August verified against observations – largely missed in NGACv2

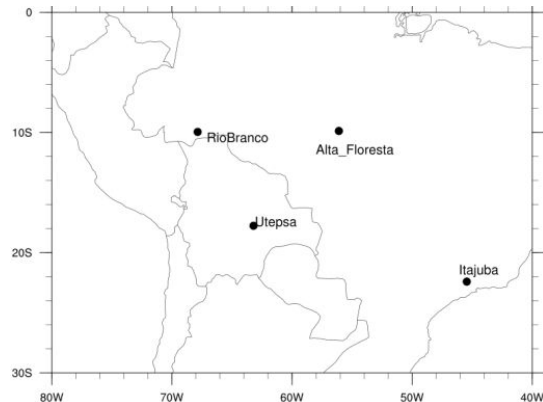


## Day 1 total AOD forecast bias for August, 2019

**GEFS-Aerosols show less bias in Total AOD prediction when compared against two different data set**

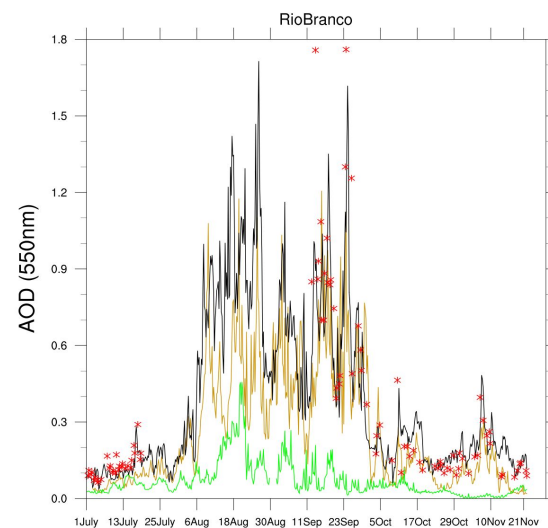
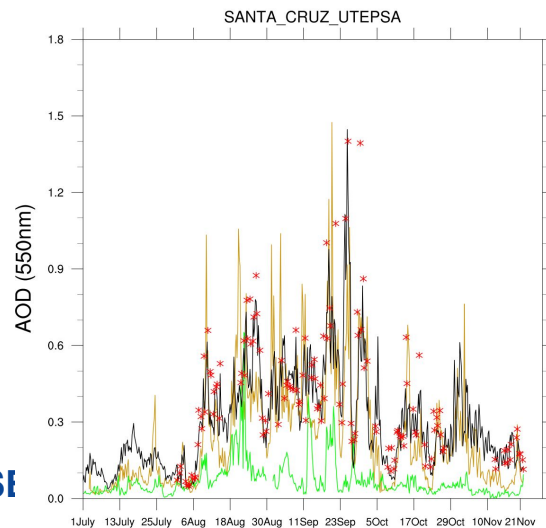
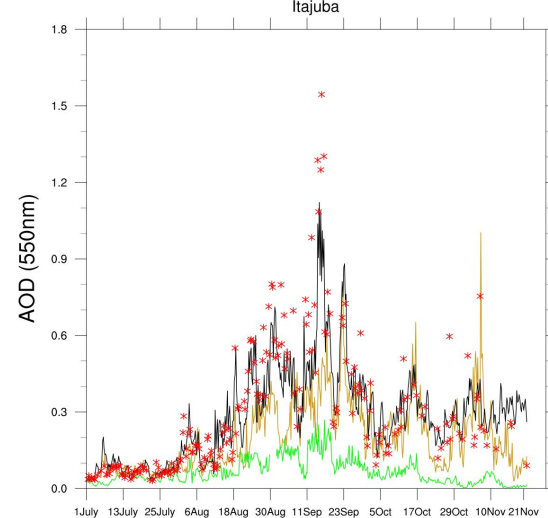
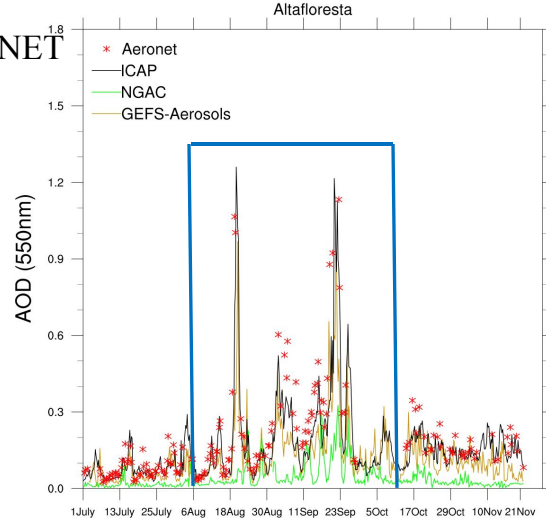


# Day 1 AOD forecast verified against AERONET



AERONET stations over S. America

**GEFS-Aerosols total AOD prediction matches closely with station data – throughout biomass burning season in S. America**

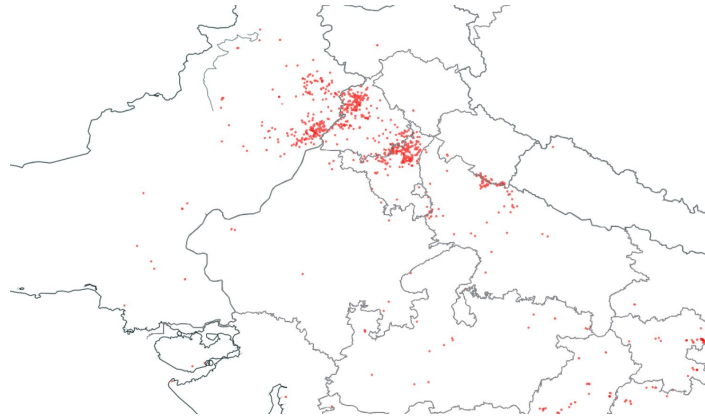


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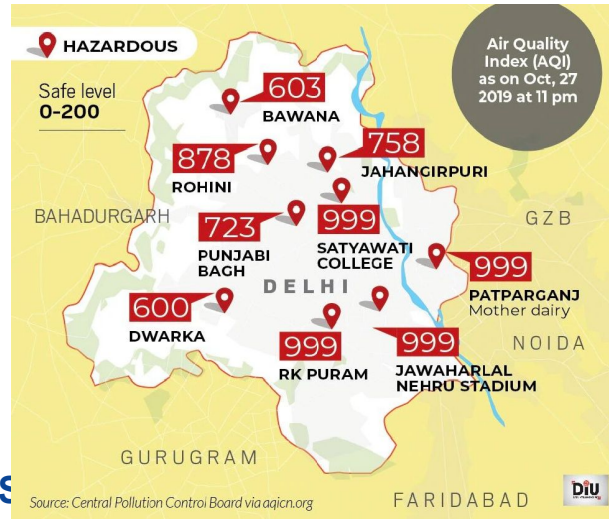
# High aerosol event : Agricultural fire and anthropogenic emission over N. India – October-November, 2019



Haze over N. India (MODIS true color image) on 4 November



Crop burning : Sumoi NPP Fire and thermal anomalies (15<sup>th</sup> October, 2019)

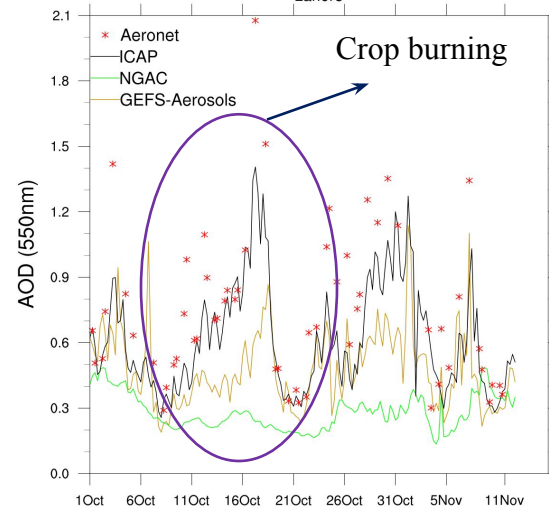
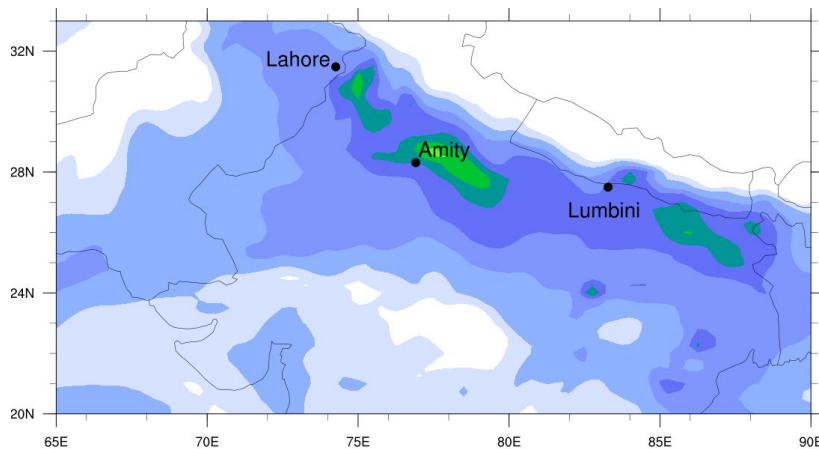


Pollution over Delhi

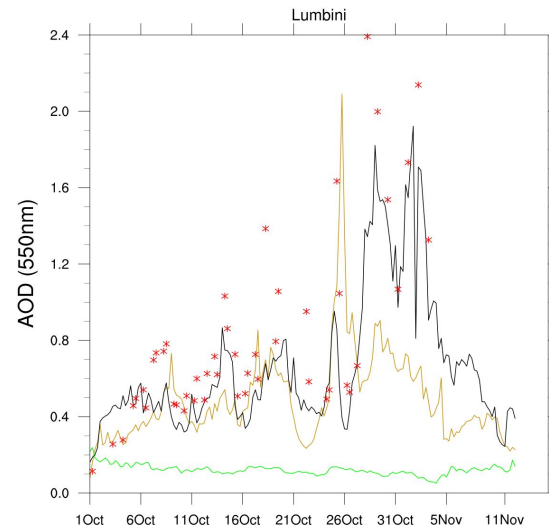
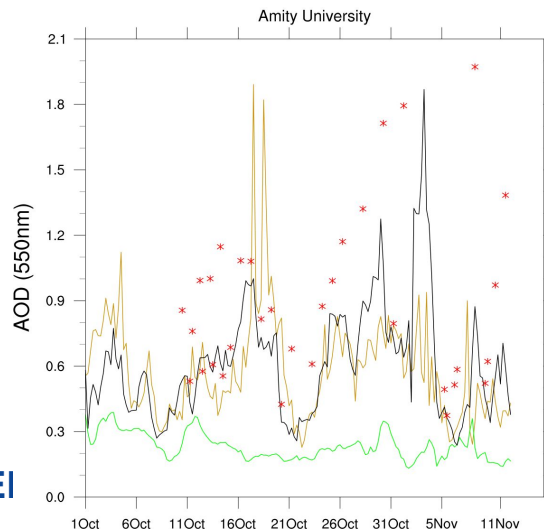




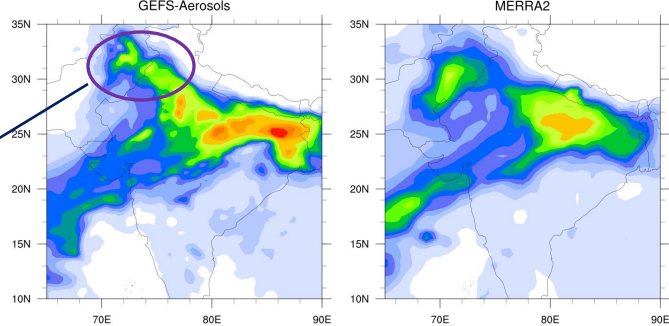
## AERONET stations



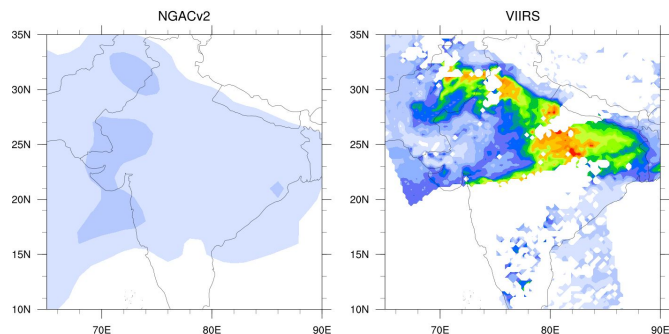
**Day 1 AOD forecast from GEFS-Aerosols show under prediction over Agricultural burning location in NW India and northern Pakistan, but result is better than NGAC**



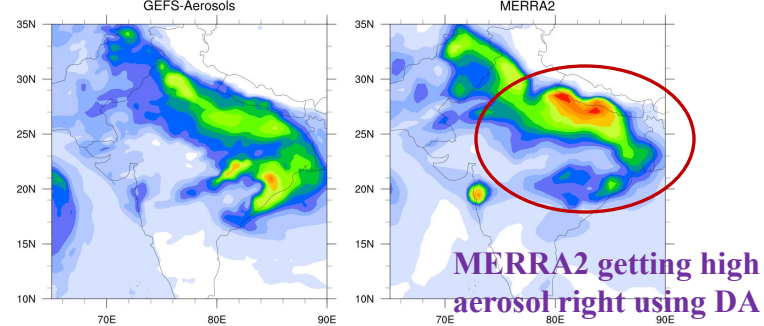
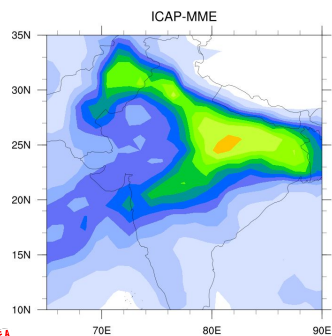
Crop  
burning  
area



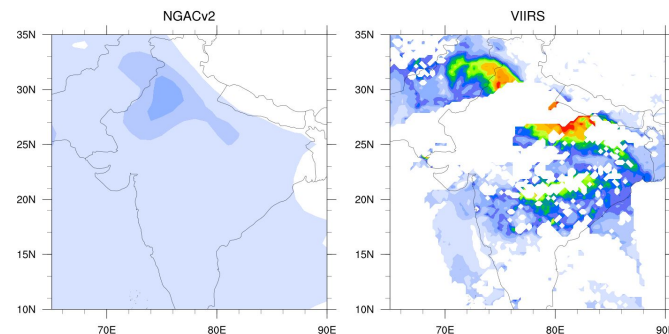
Transport of Total  
AOD from west to  
Indo-Gangetic  
plane during  
October



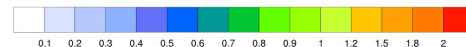
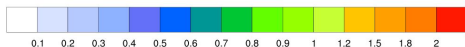
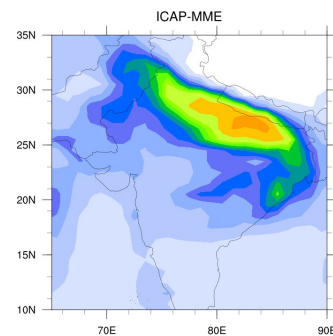
18-hour forecast on  
18<sup>th</sup> October, 2019

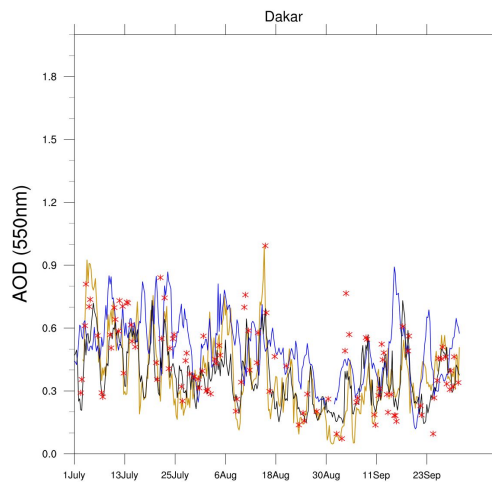
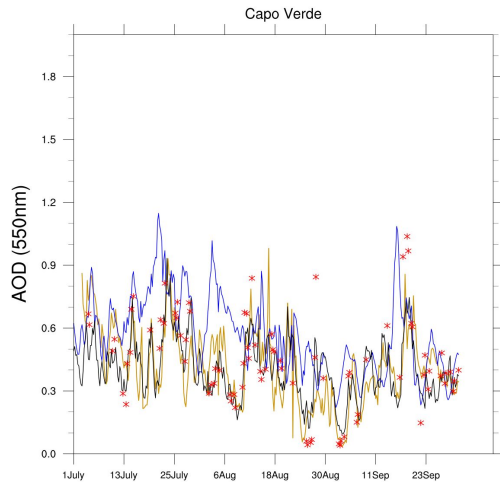
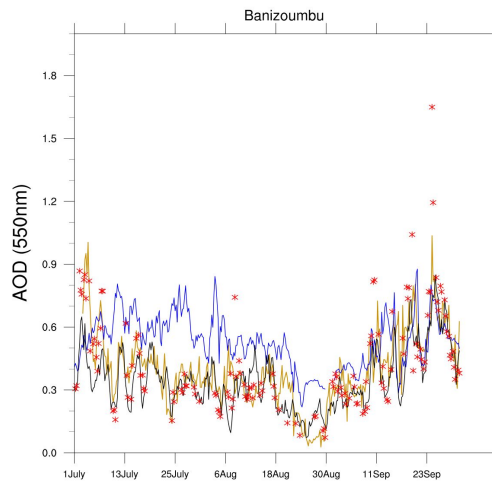
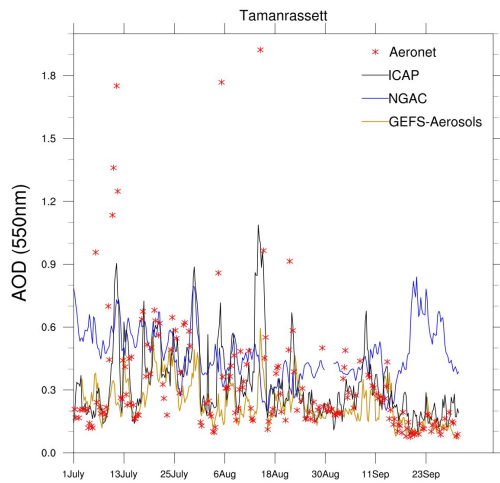


MERRA2 getting high  
aerosol right using DA

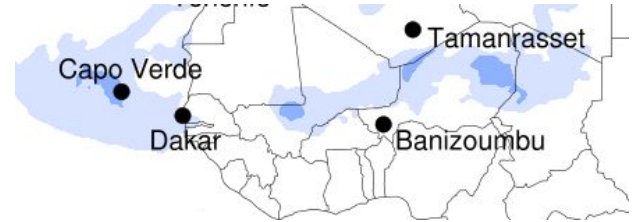


18-hour forecast on  
29<sup>th</sup> October, 2019





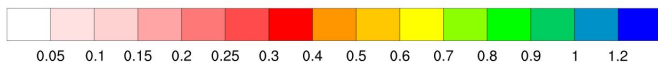
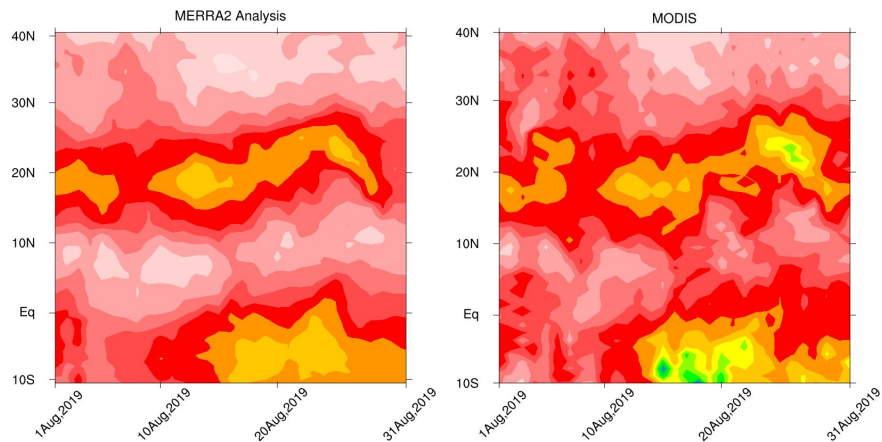
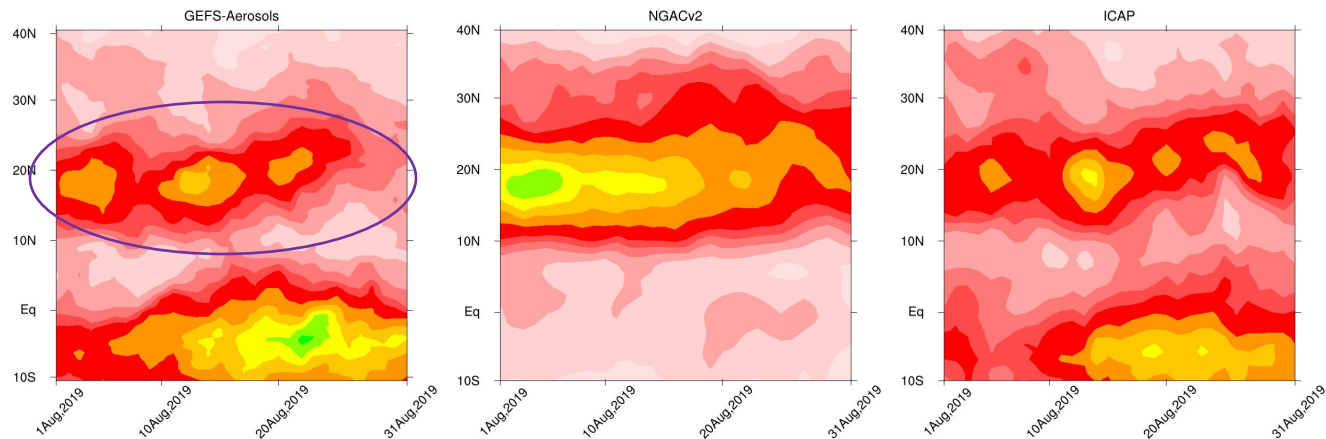
## High aerosol event : Saharan Dust



Aeronet locations over Sahara region

- ] Near dust source region (Tamanrasset),  
GEFS-Aerosols matches closely with the  
observation
- ] Some under prediction over dust outflow region

# Total AOD (Longitude average between 60W and 20E)



model AOD forecast verified against observations over N. Atlantic :

- Transport of dust between 10-30° N from GEFS-Aerosols showed similarity with observation



## Conclusions

- GEFS-Aerosols with improved tracer transport, higher resolution, use of plume rise model and GBBEPx emission showed overall improvement of total AOD forecast than the current operational NGACv2. Overall improvements of bias (less bias) over Asia, major wildfire regions are noted during this study period.
- Both near source and downwind locations of high aerosol events, AOD from GEFS-Aerosols are consistent.
- Evaluation of dust aerosol over source and downwind regions indicate good agreement with observation
- GEFS-Aerosols able to reproduce total AOD monthly/seasonal variation compared to AERONET, ICAP-MME and MERRA2 reanalysis over complex terrain over India

## Future work

- Implement near-real time 3D-VAR (GSI) based data assimilation of MODIS and VIIRS AOD retrievals at 550 nm

